Reducing Airborne Dust Particles

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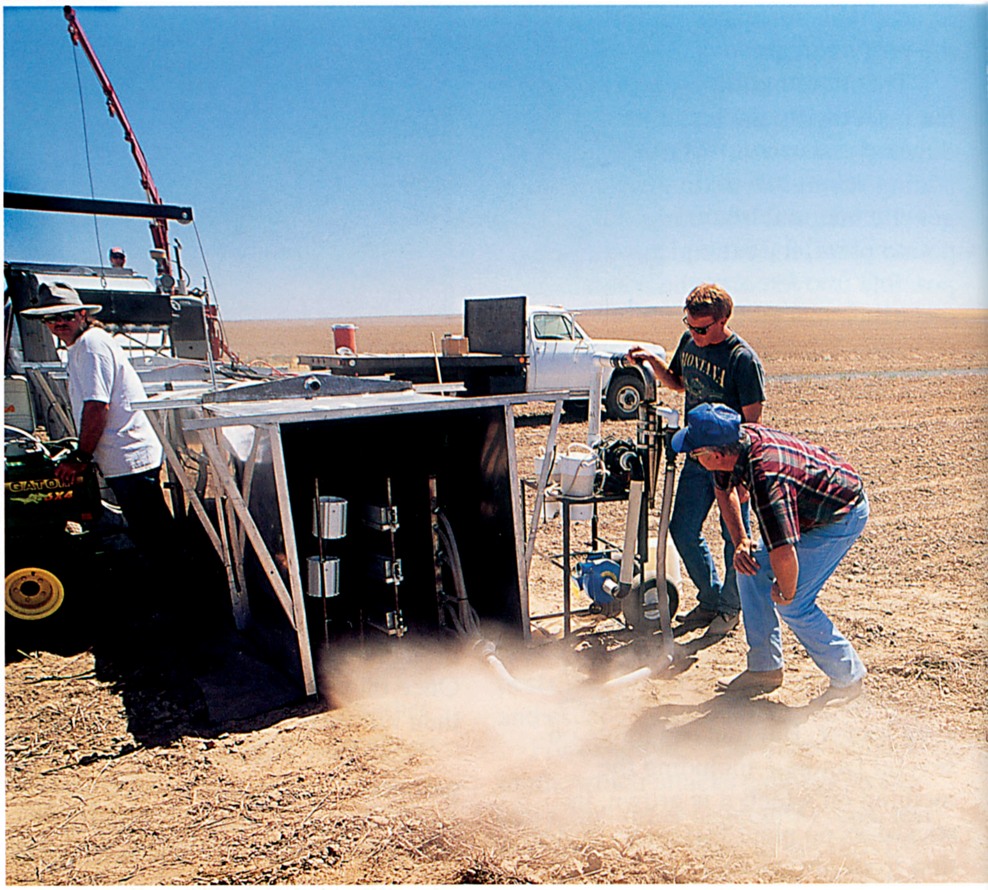

Agricultural engineer Keith Saxton (right) and technicians Jeff Ginzel (left) and Lance Horning use a portable wind tunnel to test field surface susceptibility to wind erosion and PM-10 emissions. A small whirlwind raises a dust cloud in the distance. (K7127-4)

David Roseberry's pillow was covered with dust.

The previous evening in October 1991, 60-mile-per-hour winds had buffeted part of his wheat farm and much of eastern Washington with clouds of topsoil.

"There was even dust on the dishes that had been loaded into the dishwasher and cleaned the night before," Roseberry says.

Such storms are more than just a nuisance.

"The wind sandblasts the wheat in concentrated areas and kills everything on the surface," says Roseberry. "Once it starts blowing, wind can cost us a fortune in lost crops."

And the problems don't stop at the farm. Roseberry and other farmers may soon have to worry not only about their lost soil and crops, but about the health of nearby city dwellers, as well.

"The smallest, nearly invisible dust particles, known as PM-10, can damage the lungs," says George Lauderdale. He's a senior air quality specialist with the U.S. Environmental Protection Agency (EPA) in Region 10, which covers Washington, Idaho, Oregon, and Alaska.

PM-10 stands for particulate matter less than 10 micrometers, or microns, in diameter. That's about one-seventh the diameter of one strand of human hair.

This material is so small that it stays suspended in the air over long distances, and people inhale the particles as they breathe, Lauderdale says. Our bodies generally filter out dust and air pollutants, but these tiny particles can pass through defenses in the nose and lodge in the lungs.

Typically, PM-10 can reach unhealthy concentrations in the cities. Industrial smokestacks, wood smoke from fireplaces, and dust stirred up from construction and unpaved roads are common sources.

But as urban sprawl puts cities and farms into increasingly closer contact, farmers may need to help control the dust that blows off their land.

Borne by the Wind

Wind erosion experts with the Agricultural Research Service in Washington, Texas, and Kansas are helping farmers and air quality authorities understand the relationship between wind erosion on agricultural lands and PM-10 in the cities. Their goal: to protect soils, crops, and human health.

"PM-10 is another facet of wind erosion. ARS scientists have been helping farmers manage wind-driven soil erosion since the Dust Bowl of the 1930's, when severe windstorms battered the Southern Plains," says ARS agricultural engineer Keith Saxton of Pullman, Washington.

But smaller, intense dust storms still blow across America's farmlands every few years, especially in dry areas like the Columbia River Plateau. This 50,000-square-mile area spanning eastern Washington, northern Oregon, and western Idaho is the focus of a joint project between ARS, EPA, and university scientists to understand and control wind erosion and PM-10.

A 5-year research project underway in the Pacific Northwest's Columbia Plateau tests farming systems that reduce wind erosion and fine dust.

Roseberry's land is typical of this fertile area. Dryland farming of the silty volcanic soils in the Columbia Plateau produces much of the nation's soft white winter wheat, used for cookies and noodles. But nearby cities like Spokane and Kennewick, Washington, have had some of the nation's highest PM-10 levels.

By 1997, the EPA is required to characterize and propose ways to manage PM-10. But regulators don't want to impose a burdensome solution on agriculture.

"The federal Clean Air Act of 1990 was designed to deal with stagnant, predictable sources of PM-10, not seasonal violations caused by drought conditions and high winds," says David Lauer, Director of the Clean Air Authority in Benton County, Washington.

"EPA is being as flexible as possible while the scientists do their analyses," he says. Lauer's agency has local authority for implementing federal regulations.

How Much PM-10 Leaves the Farm?

Saxton is leading a 5-year project in the Columbia Plateau to measure agriculture's contributions to urban PM-10, develop methods for tracing dust back to specific agricultural sources, and test farming systems to reduce wind erosion and fine dust.

The first step, says Saxton, was to find out whether dust blowing off farms was PM-10 and determine how much of the dust was made up of larger particles.

He set up measuring stations in three farmers' fields across the plateau. He used both standard equipment for measuring wind erosion and the PM-10 monitoring equipment principally used in cities.

"We're measuring all the variables of wind and soil movement from the ground up to 15 feet," he says. When the windspeed reaches 15 miles per hour, the instruments are activated and the data recorded electronically.

"Not surprisingly, our preliminary results confirm that dust blown off dry fields contains PM-10," says Saxton. "What's surprising is how much—10 to 15 times more than would come off soils with higher clay content."

But these intensive field sites represent only three specific field situations.

"There are many types of field conditions—including the size and shape of soil clods, amount of standing plant material left from the previous crop, and soil type," says Saxton. "Combinations of these variables may hold the soil and the PM-10 in place to different degrees."

To test a wide range of conditions that occur naturally in the area, Saxton and colleagues use a portable wind tunnel. The tunnel, which is about 45 feet long, 3 feet wide, and almost 4 feet high, sits on the soil surface. A large fan sends winds of predetermined speeds blowing across the soil that forms the floor of the tunnel.

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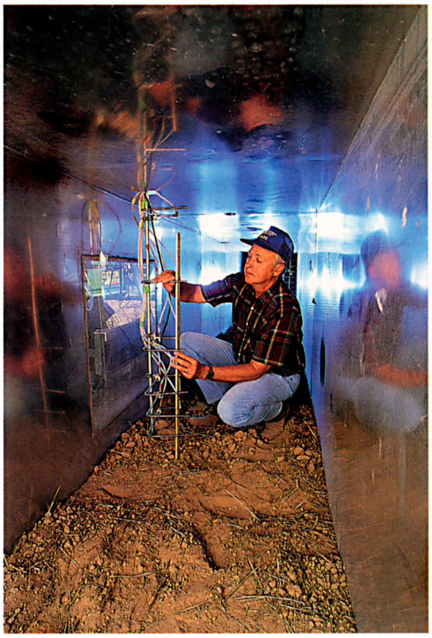

Before installing dust-gathering equipment, agricultural engineer Keith Saxton adjusts wind measuring devices inside the portable, 45-foot wind tunnel. (K7123-1)

"With the wind tunnel, we can test the resistance of different soil conditions to wind erosion and measure PM-10 emissions," Saxton says. The scientists can measure about 50 test plots in 3 weeks with this tool.

The information will be used to derive mathematical relationships between wind erosion and fine dust.

"When we understand these relationships, we'll be able to predict the severity of PM-10 emissions during wind erosion events and test the effectiveness of control mechanisms," says Saxton.

He is pooling his results with ARS agricultural engineers Lawrence J. Hagen in Manhattan, Kansas, and Donald W. Fryrear in Big Spring, Texas, who are evaluating similar relationships.

In contrast to the Pacific Northwest, Great Plains farmlands have heavier, clayey soil with fewer small, loose particles that readily become airborne, says Hagen.

Compared to the maximum of 4 percent of dust that is 10 microns or under in Columbia Plateau soils, Kansas soils rarely contain more than 0.25 percent.

Predicting how much PM-10 air pollution can be expected from various soils and weather is part and parcel of a computer model called WEPS—Wind Erosion Prediction System. WEPS was developed and is under revision by a national team of ARS scientists led by Hagen. [See "Stemming Wind Erosion," *Agricultural Research*, June 1994, pp. 8-15.] Knowledge gained by Saxton, Hagen, and Fryrear will play a key role in the PM-10 parts of WEPS.

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Atop the roof of a high school in Kennewick, Washington, meteorologist Mary Hattendorf changes a 10-micron filter on a high-volume dust sampler. Dave Lauer (wearing cap), Clean Air Authority director in Benton County, Washington, and meteorological technician John St.Clair inspect the filters on another dust sampler. (K7124-1)

Hagen and his colleagues have identified three ways that PM-10 escapes from the rest of the soil. All three are initiated by bouncing, or saltating, soil particles.

First, saltating soil splashes up loose PM-10 that is resting on the surface of larger dirt particles. Second, PM-10 can slough off as saltating particles beat against clods and crusts of dry soil. Third, as winds bounce soil particles along the ground, these particles also break up larger soil aggregates and dislodge additional PM-10.

But which type of soil is likely to produce most of the PM-10 pollution? The answer, says Hagen, may be different in each region and may depend partly on how well the soil is managed.

Sandy soils in Kansas where grain sorghum is commonly grown are most likely to erode, especially when little crop residue is present. Such soil contains fewer PM-10 particles than other soils. Soils high in clay, where wheat is grown, are generally covered with more crop residue. The clay binds soil aggregates together, reducing the likelihood of erosion.

But when mixed sandy-clay soils are exposed to erosion over long periods, the result may be areas of sandy, less fertile soil that are highly susceptible to more erosion.

In eastern Washington, Roseberry noted that patches of such sandy soil have appeared after several seasons of drought and wind.

The main processes producing airborne PM-10 from Kansas soils turned out to be breakdown of soil aggregates that were bouncing along and abrasion of larger clods and crusts. To research both phenomena, the Manhattan scientists also used a wind tunnel.

They conducted several experiments to see how the sources should be accounted for in a PM-10 prediction module of the WEPS erosion submodel.

"We're now analyzing our experimental data, relating it to already known intrinsic soil properties such as sand, silt, and clay content," says Hagen. The scientists are proceeding with similar studies with soils from neighboring states.

Quantifying agriculture's PM-10 contribution—and ensuring that regulatory agencies will accept the data—hinges on accurate measurement. But ARS' Fryrear in Big Spring says that tools designed to measure wood smoke and industrial particulates in the cities may not work on the farm.

The problem, Fryrear says, is that the samplers seem to be collecting particulates larger than 10 micrometers in diameter under high wind conditions.

The amount of PM-10 collected is obtained by weighing the sampler's filter. If larger, heavier particles are also trapped, they incorrectly inflate the measured PM-10 concentration.

Fryrear has modified samplers to prevent the larger particles from entering and has tested them for the last 3 years in several states, as well as in Saxton's and Hagen's studies.

"Now we have to make sure our modifications haven't changed the instrument's ability to sample the fine material," he says.

Tracking Dust to Its Source

Another important task is tracing the source of agricultural dust in a large area like the Columbia Plateau, which has about 30,000 square miles of farmland.

"If you know where the source is, it's easier to develop control measures and to evaluate whether they are working," says Ann Kennedy, ARS soil scientist in Pullman.

Kennedy has developed a new approach to identifying the geographic origins of PM-10 emissions.

"Until now, we've relied on chemical analysis of the deposits on the filters. This tells us the type of soil and its chemical composition," she says. "That's really good for identifying the differences between soil and smokestack emissions or automobile exhaust, but not for separating agricultural and road dust from all over the region."

Instead, Kennedy's looking at the biological parts of the soil.

"Every soil particle has a certain resident microbial community on it. These living or dead organisms are more indicative of activities over the last hundred years than geologic

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Soil microbes can be used to trace dust to its source. Here soil microbiologist Ann Kennedy checks a computer map that shows the location of various biological groupings across the Columbia Plateau in Washington State. (K7126-1)

variables like mineral type that span tens of thousands of years," she says.

Using molecular techniques, Kennedy is developing fatty acid and DNA "fingerprints" of the microscopic communities that lived on the surfaces of soil particles caught on the samplers' filters.

"We're developing a library of soils from around the Columbia Plateau. Then we compare the fingerprints we find in the PM-10 samples to our library, to narrow down the origin of the airborne particles," she says.

So far, Kennedy and colleagues have identified five major biological groups, based on fingerprint patterns from the Columbia Plateau.

"For any type of soil that makes up over 20 percent of the filter deposits, we can trace the PM-10 source," she says. "That means we pinpoint a county-sized area, rather than an individual farm—though smaller sized areas may be possible as our library increases." The ultimate goal, of course, is to reduce all types of soil losses from wind erosion, including PM-10. Many studies in the interagency project are testing alternative control methods.

ARS weed scientist Frank Young heads up a multidisciplinary study to develop farming systems that will help. This new, 5-year study will compare the following crop rotations:

- traditional soft white winter wheat/fallow
- soft white spring wheat/fallow
- hard red spring wheat every year
- hard red spring wheat/spring barley.

Dust stirred up by field tillage shows the potential for wind-blown particulate emissions from dry, susceptible soils. Tillage dust is generally not considered as serious as wind erosion dust in the expanses of the Columbia Plateau. (K7128-1)

All rotation systems except the first will use either greatly reduced or no tillage.

Dryland farmers like Roseberry in the Columbia Plateau use the wheat-fallow cycle because of the low rainfall. Winter wheat is one of the most valuable crops in the Pacific Northwest, but there is not enough moisture in the soil to support a crop every year. During the fallow season, the soil retains water for use by the next year's crop.

"But farmers have to till more often in the fallow year to control weeds. That makes the soil vulnerable to wind erosion and PM-10 emissions," Young says.

Young believes an annual spring wheat crop might work better.

"Spring wheat has a shorter growing cycle, so it uses less water overall than winter wheat. We're also suggesting greatly reduced tillage with our systems, which should also save water. This means there should be enough moisture to support a crop every year," he says.

The challenge, Young says, will be to find the best practices, such as row spacing and fertilization, to make the system profitable to farmers.

"With continuous spring cropping—that is, no fallow cycle—we'll have crop residue on the soil surface almost all year. We'll leave standing stubble over winter and directly plant the next year's spring crop right into the residue," he says.

Though not working directly with Young, Roseberry is also experimenting with continuous spring wheat cropping.

"It probably won't be practical to convert the whole countryside to continuous cropping, but it could be another tool to stabilize the situation. Growers have plenty of motivation to keep the soil from blowing, but we need to find out which practices work best," he says.—By **Kathryn Barry Stelljes** and **Ben Hardin,** ARS.

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